

# GY111 Introductory Geology

## Lecture 8: Geologic Time Measurement



# Geological “Clocks”

- Geologic time determination is subdivided into 2 categories:
  - Relative Dating: simply determines whether or not an event occurs before or after another event (e.g. a granite dike is younger than the surrounding sandstone since it intrudes across the sandstone in an outcrop)
  - Absolute Dating: assigns a date to an event in terms of years before present with an error bracket (e.g. 366 Ma +/- 5 Ma)



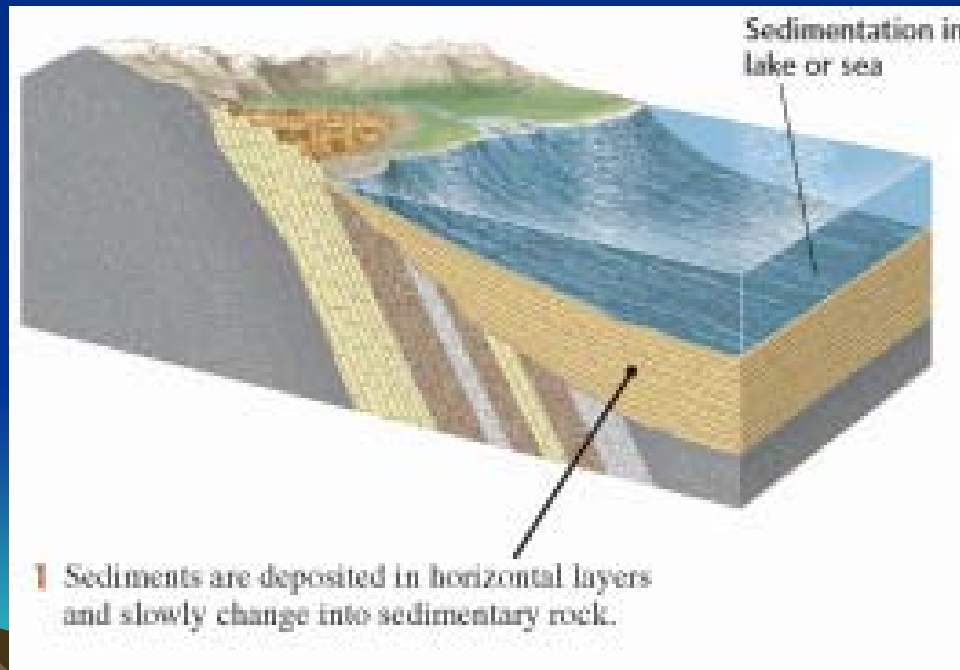
# Stratigraphic Principles

- Principle of Original Horizontality: layers of sedimentary strata are assumed to be deposited in a horizontal or near horizontal orientation
- Principle of Superposition: in a sequence of undeformed strata the younger layers are uppermost in the sequence
- Principle of Faunal Succession: life has evolved over time therefore more recent life forms occur only in young strata



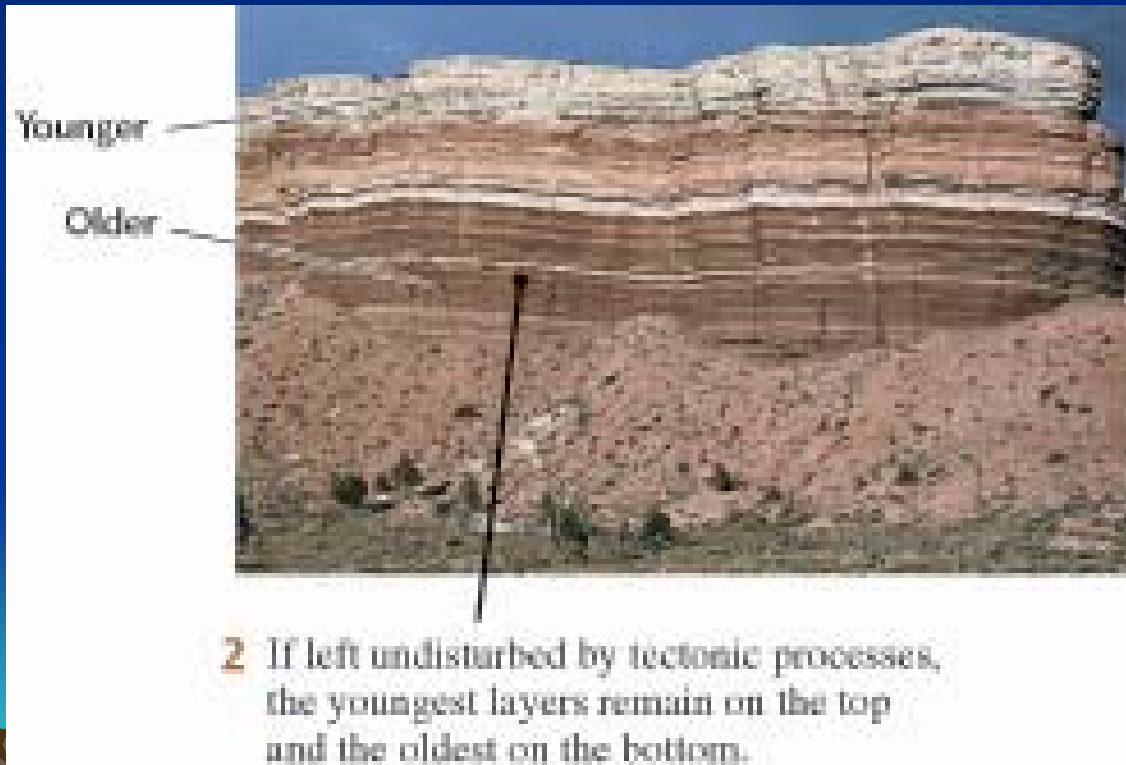
# Original Horizontality

- Sediments are deposited horizontally or nearly so



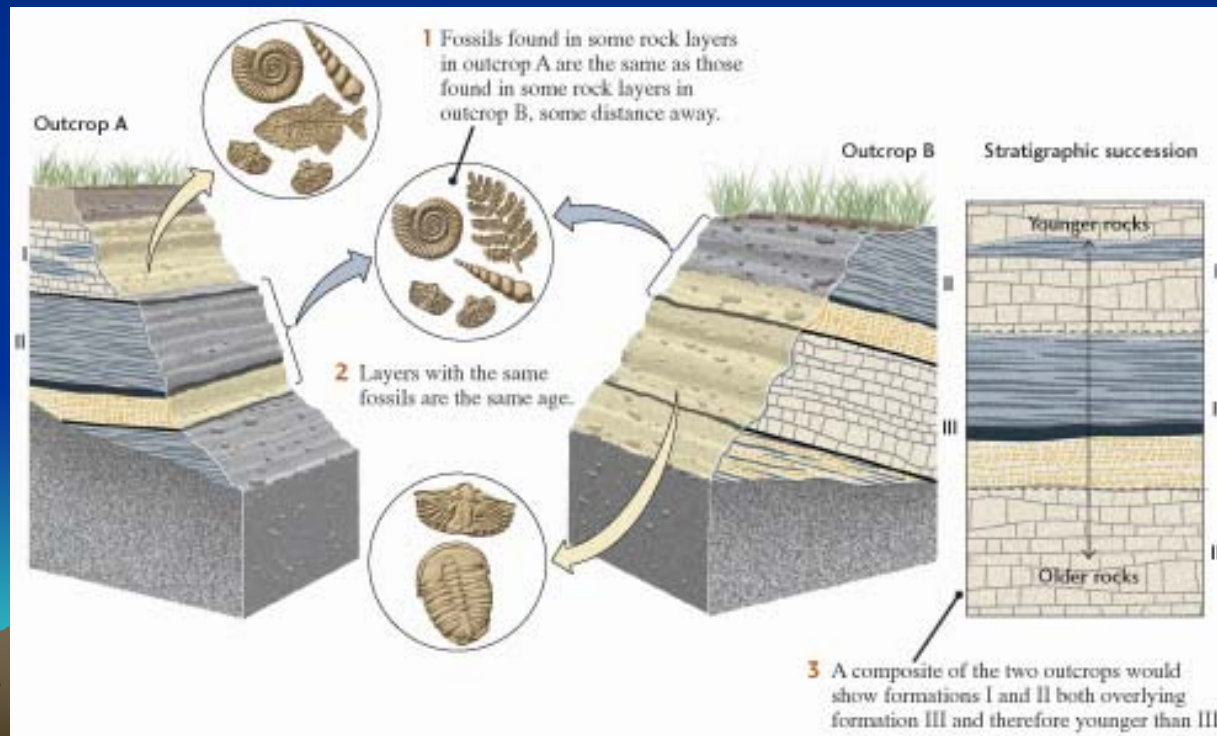
# Superposition

- Layers on top are younger than those below



# Faunal Succession

- Fossils display a progression of increased complexity over geologic time
- Strata deposited at the same time will display similarities in fossil content



# Cross-cutting Relationships

- If a body of rock cuts across another it must be younger than the rock it cuts
- If an inclusion of one type of rock is found contained in another the inclusion must be older than the surrounding rock



# Example: Cross-Cutting

- Granite dike intruding sandstone and shale



# Example: Inclusion

- Granite contains pieces of country rock that are completely surrounded (xenoliths)



# Unconformities

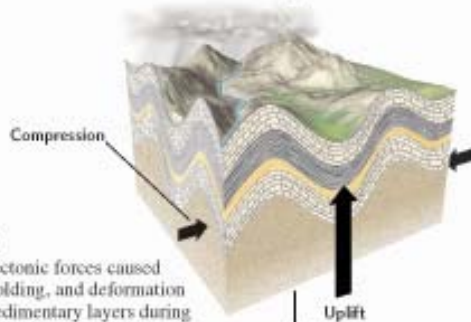
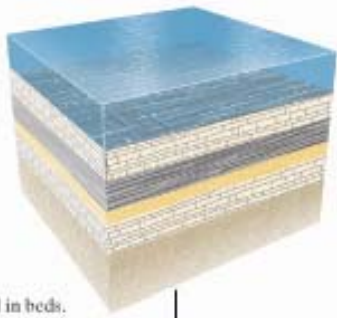
- Represent erosional events where strata is removed, or is simply a time of non-deposition
- Types of Unconformities:
  - Angular: tilted layers of strata below unconformity
  - Disconformity: layers above and below unconformity are parallel to the unconformity
  - Nonconformity: crystalline rocks are found below the unconformity, sedimentary rocks above



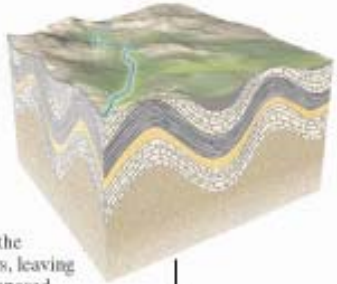
# Angular Unconformity

- Requires a period of deformation before uplift causes erosion of unconformity surface

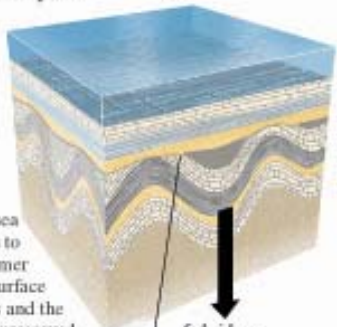
TIME 1  
Beneath the sea,  
sediments accumulated in beds.



TIME 2  
Later, tectonic forces caused  
uplift, folding, and deformation  
of the sedimentary layers during  
mountain building.



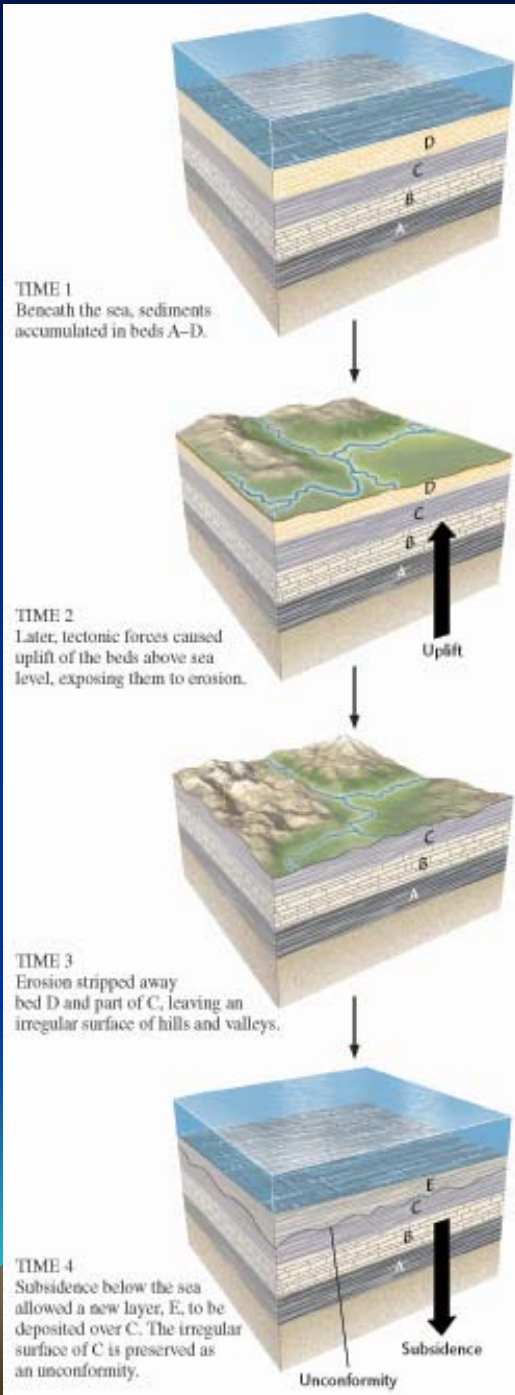
TIME 3  
Erosion stripped away the  
tops of the folded layers, leaving  
an uneven plain with exposed  
portions of several folded layers.



TIME 4  
Subsidence below the sea  
allowed new sediments to  
be deposited on the former  
erosion surfaces. The surface  
where the folded layers and the  
new sediments meet is preserved  
as an angular unconformity.

# Disconformity

- A disconformity usually represents a relatively short interval of erosion and/or non-deposition



# Nonconformity

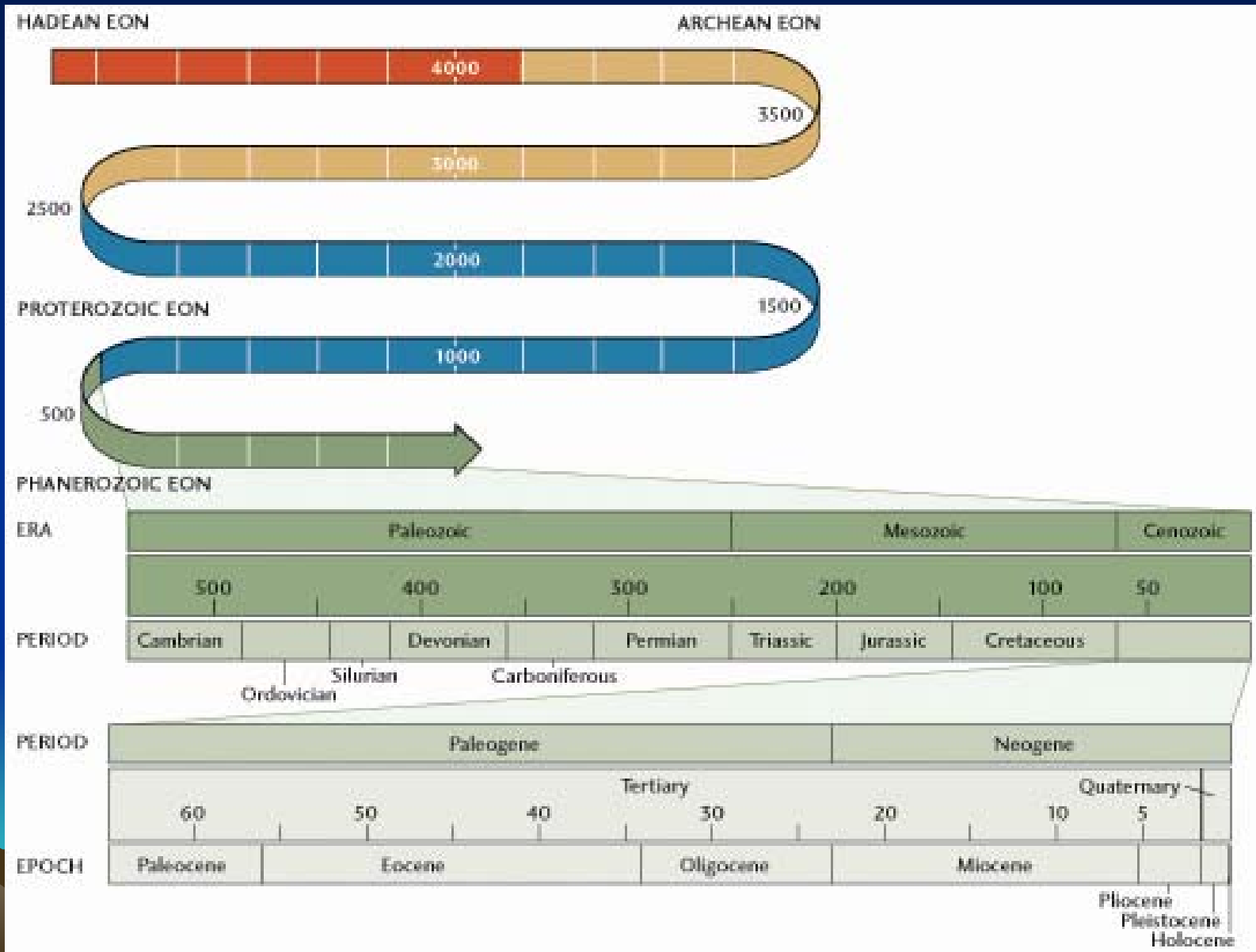
- Nonconformities indicate large time intervals of erosion and/or non-deposition

Tapeats Sandstone

Vishnu Schist



# Geologic Time Scale



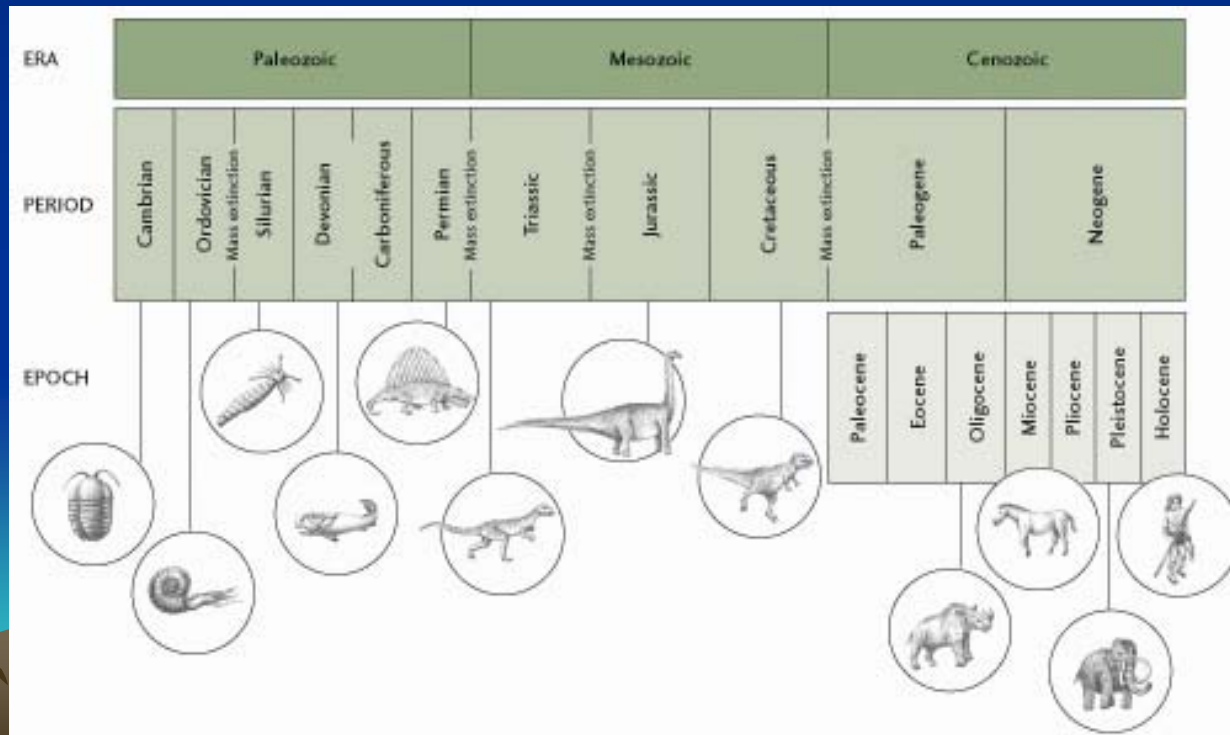
# Review for Lecture Test 2

- Chemical weathering reactions
- Soil Types and Profiles
- Sedimentary Environments
- Classification of Clastic and Chemical Sedimentary Rocks
- Sedimentary Structures
- Types of Metamorphism
- Metamorphic Facies
- Unconformities
- Relative Dating Techniques
- Geological Time Scale (Eons & Eras with benchmark dates)



# Phanerozoic Life

- Evolution of complex animals with hard body parts began with the Cambrian Explosion



# Cambrian Explosion

- Why?
  - Buildup of oxygen in atmosphere and oceans allowed for evolution of gills
  - Hard shells are evolutionary advantages
  - Recent breakup of the super continent of Rodinia provided abundant shallow continental shelf habitat for reef organisms



# Mass Extinctions

- Life on Earth has evolved under conditions of “punctuated equilibrium”- long periods of little change punctuated by mass extinctions followed by rapid evolution
- Meteorite Impacts: responsible for the K-T extinction (75% of all species extinct)
- Super Eruptions: Siberian eruptions at P-Tr boundary caused extinction of 95% of all species



# Absolute Dating: Radiometric

- Radiometric dating depends on the systematic decay of radioactive isotopes
- Measurement of the very small quantities of Parent and Daughter isotopes requires a very specialized analytical instrument – Mass Spectrometer



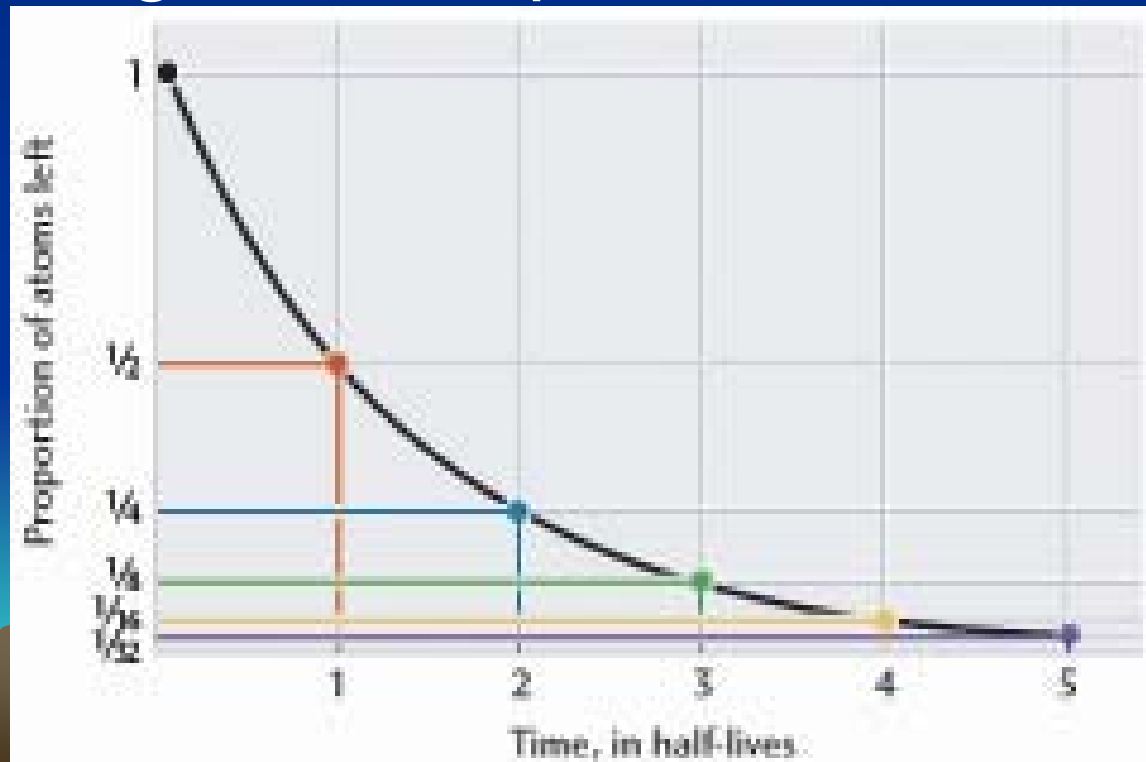
# Radiometric Systems useful in Geology

- Useful geologic radiometric systems must have parent isotopes that are common in rocks
- The rate at which the parent isotope decays must be slow enough to date long spans of geologic time

Isotopes		Half-Life of Parent (years)	Effective Dating Range (years)	Minerals and Materials That Can Be Dated
Parent	Daughter			
Uranium-238	Lead-206	4.4 billion	10 million–4.6 billion	Zircon Apatite
Uranium-235	Lead-207	0.7 billion	10 million–4.6 billion	Zircon Apatite
Potassium-40	Argon-40	1.3 billion	50,000–4.6 billion	Muscovite, Biotite Hornblende
Rubidium-87	Strontium-87	47 billion	10 million–4.6 billion	Muscovite, Biotite Potassium feldspar
Carbon-14	Nitrogen-14	5730	100–70,000	Wood, charcoal, peat Bone and tissue  Shells and other calcium carbonates

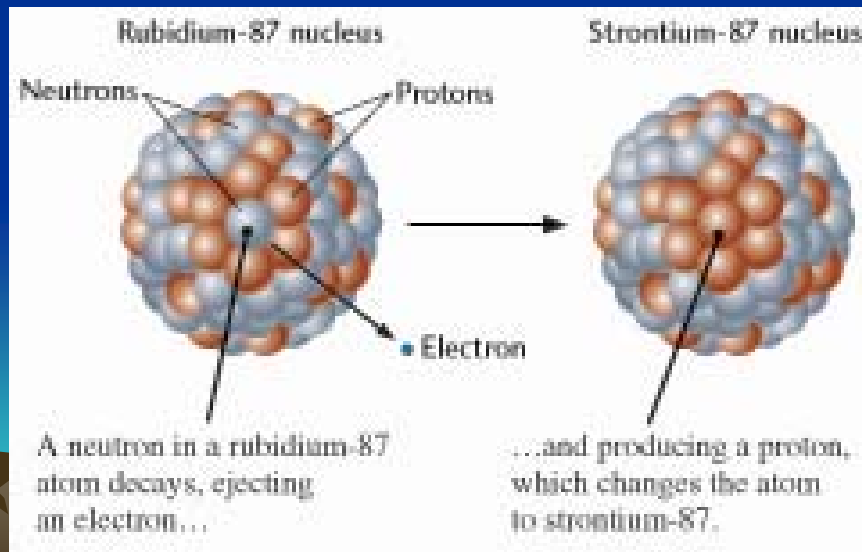
# Radioactive Decay and Half-Life

- The half-life period is the amount of time it takes  $\frac{1}{2}$  of the parent isotope to decay to the daughter isotope



# The Process of Radioactive Decay

- Consider  $\text{Rb}^{87}$  decaying to  $\text{Sr}^{87}$
- The superscript is the mass number, the atomic number of Rb and Sr is 37 and 38 respectively



Rb (37 protons + 50 neutrons) = 87

Sr (38 protons + 49 neutrons) = 87

One neutron in Rb ejects an electron turning it into a proton

# Problems Associated with Radioactive Age Estimates

- Isotopes are biased toward Felsic compositions
- Cannot date sedimentary rocks
- The age of a metamorphic rock is its recrystallization event
- U-Pb is sensitive to contamination
- K-Ar is sensitive to loss of daughter product
- There must be enough parent & daughter isotope to be detectable
- Estimates of age are subject to geological interpretation

